N7970048

POSSIBLE APPROACH TO PHASING FOR UNMANNED RENDERZVOUS - CASE 610

BELLCOMM, INC.

FEB 68

BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Possible Approach to Phasing for Unmanned Rendezvous - Case 610

DATE: February 29, 1968

FROM: K. E. Martersteck

ABSTRACT

A phasing scheme suitable for rendezvous of an unmanned chase vehicle with a manned target is presented. This phasing scheme takes advantage of the fact that in the rendezvous of an unmanned chase vehicle with a manned target, the terminal phase must be executed from above the target. Large down-range insertion errors can be corrected in a relatively simple manner with a minimum of maneuvering by portioning the time spent by the chase vehicle in a circular parking orbit below the target versus time in a coelliptic orbit above the target at TPI altitude.

(NASA-CR-157808) POSSIBLE APPROACH TO PHASING FOR UNMANNED RENDEZVOUS, CASE 610 (Bellcomm, Inc.) 9 p

N79-70048

Unclas
00/13 36831

Y68-83008
(ACCESSION NUMBER) (THRU)
9
(PAGES) (CODE)
CR-93608
(NASA CR OR TMX OR AD NUMBER) (CATEGORY)
FF No. 602(A)
AVAILABLE TO NASA OFFICES AND NASA RESEARCH CENTERS ONLY

SUBJECT: Possible Approach to Phasing for Unmanned Rendezvous - Case 610

DATE: February 29, 1968

FROM: K. E. Martersteck

MEMORANDUM FOR FILE

INTRODUCTION

The feasibility of unmanned rendezvous and docking for AAP missions, in particular for the AAP-4 LM/ATM mission, is currently being studied.[1] If the LM/ATM can execute an unmanned rendezvous and docking to the cluster, several operational problems extant in the present AAP-3/AAP-4 baseline would be either eased considerably or eliminated completely. For example, by deleting the AAP-3 CSM propellants required for a second rendezvous, the payload weight for that mission would be within the launch vehicle capability. Also, the time between LM/ATM launch and final docking would be much shorter, thereby relieving the burden on batteries for electrical support to the LM/ATM prior to solar panel deployment. Crew operations such as probe/drogue manipulations would be simplified; crew safety would be enhanced since the crew would no longer be split between two separately-flying vehicles with one vehicle being operated by one man alone.

RENDEZVOUS MODES

Two basic modes for unmanned rendezvous and docking are being considered: automatic and manual remote. In the automatic mode all computations and control of maneuvers would be handled on board the chase vehicle (the LM in the AAP-4 case) using its own guidance and control system. In the manual remote mode, pre-TPI (terminal phase initiation) maneuvers would be computed on the ground, sent up to the chase vehicle and initiated by an on-board clock. The terminal phase maneuvers (from TPI through braking) would be handled from the cluster either by computation on the cluster and execution by the chase vehicle clock or by direct commands in real time from the cluster crew.

RENDEZVOUS PROFILES

Analysis plus Gemini experience has shown that with TPI in daylight near sunset, a darkside TPI-TPF transfer angle of about 130°, and braking at dawn, the resulting visibility conditions, line-of-sight rates, etc., are conducive to a well-controlled rendezvous with manual backup to computer computation readily available. For the case of a manned rendezvous, i.e. crew in the chase vehicle, these lighting conditions together with the requirement that the target be illuminated by the sun generally along the crew line of sight can be satisfied only by a rendezvous in which the chase vehicle approaches the target from below and behind.

Regardless of which unmanned rendezvous mode is used, it has been established that the terminal phase approach of the chase vehicle must be visible to the crew in the cluster with lighting conditions similar to those of a manned rendezvous. This implies that the unmanned rendezvous must be made from above and ahead of the cluster. As shown in Figure 1, this ensures comparable lighting along the line of sight of the crew at corresponding points of the manned and unmanned rendezvous approaches. It is also desirable that the unmanned rendezvous be completed reasonably expeditiously.

A primary objective of pre-TPI maneuvers starting with the launch itself is to have the chase vehicle arrive at the TPI point at the right time to ensure the desired terminal phase lighting. Because of insertion dispersions it is necessary to plan a sequence of in-orbit maneuvers (usually called phasing maneuvers) to adjust the relative motion of the chase vehicle with respect to the target in order to ensure the arrival of the chase vehicle at the TPI point at the appointed time. The principal dispersion which must be corrected is down-range position. Since the Saturn launch vehicles guide on altitude, flight path angle and velocity, the time of insertion and the down-range insertion point are open-loop parameters. However, because of the correlation between insertion range and time, in the context of relative motion with respect to a target vehicle in orbit the effects of these insertion parameters may be combined as an effective insertion range error. On this basis for low-altitude missions such as the Apollo 5 mission (initial orbit 85 x 120 nm), the 1σ variation in insertion range is about 15 nm. A detailed dispersion analysis has not been run for the higher altitude ($\sim$210 x 210 nm) AAP-4 type mission. However, it is anticipated that the AAP-4 down-range dispersions will be at least the magnitude of the low-altitude case and more likely as great as 1σ = 25 nm.[2]

In manned-rendezvous situations where the TPI point is below the target altitude, all phasing maneuvers are usually performed at or below the TPI altitude in order to minimize the Δv propellant requirements. The result is that the chase vehicle is continually "catching up" to the target and the phasing maneuvers are used to adjust the catch-up rate.

To date in the unmanned-rendezvous studies, only modified versions of the manned-rendezvous phasing schemes have been considered. A typical profile, shown in Figure 2, is characterized by an elliptical insertion orbit, orbit-adjust maneuvers at the apsides of the orbit and a separate phase-adjust orbit with apogee at the TPI altitude.

PHASING FOR UNMANNED RENDEZVOUS

It is possible to take advantage of the necessity of the unmanned rendezvous to be from above the target to develop a relatively simple, yet very flexible scheme for phasing. A sample profile is shown in Figure 3.

The scheme is first of all characterized by insertion into a circular rather than elliptical parking orbit below the target. This has two principal advantages. First the launch vehicle's second stage is kept well clear of the target. The apogee of the elliptical insertion orbit presently being considered is somewhat constrained by the requirement that the spent S-IVB stage remain well clear of the target in the worst dispersion case. Secondly the circular orbit insertion affords complete freedom in the choice of subsequent maneuver times rather than having maneuvers constrained to occur at the apogee or perigee of the parking orbit to conserve propellant. The choice of altitude for the circular parking orbit is made by trading off launch vehicle capability versus chase vehicle rendezvous propellant capacity. Using a circular parking orbit of radius equal to the semi-major axis of the proposed elliptical insertion orbit would result in essentially the same orbital payload and rendezvous Δv requirements.

The phasing is accomplished by simply executing a Hohmann transfer from the parking orbit to the coelliptic orbit containing the TPI point at a time calculated to ensure arrival at the TPI point at the scheduled time. Despite large down-range dispersions, the chase vehicle can readily arrive on-time at TPI. For example, referring to Figure 3, if the chase vehicle is inserted at the $+3\sigma$ point instead of the nominal point, the transfer maneuver is delayed past the nominal transfer time until the extra time spent in the parking orbit plus the extra time in the coelliptic orbit equals the nominal time in the parking orbit lost because insertion took place at $+3\sigma$. Similarly, if insertion occurs at -3σ, the transfer maneuver would be executed before the nominal transfer time to produce an on-time arrival at TPI. Figure 3 shows the parking orbit the same distance below the target as the coelliptic orbit is above. This has been done only for convenience of illustration and is not necessary to make the phasing scheme work. Once the insertion point is known, a straightforward calculation working back from desired time at TPI will yield the correct time for the transfer maneuver regardless of the parking orbit altitude.

The phasing scheme presented above reduces the number of required maneuvers to a minimum for a coelliptic rendezvous. Furthermore, the magnitude of the Δv burns will be known in advance and only the time of the transfer maneuver must be calculated after insertion. The principal disadvantage of the proposed scheme is the variation in the time of the transfer maneuver. However, since the chase vehicle is unmanned, no crew activities which need be interleaved with the maneuvers would be impacted. The variation in maneuver time results in firing thrusters over various portions of the ground track. However, there is actually no requirement that all maneuvers be made over a ground tracking station, although this would be desirable.

It should be noted that the above discussion was primarily concerned with the effects of down-range insertion errors. Clearly there will be small errors in altitude and out-of-plane velocity components which must also be corrected. These adjustments could be readily accomplished along with the transfer maneuvers or by a separate corrective combination maneuver.

CONCLUSION

An unmanned rendezvous phasing scheme has been presented in which large down-range insertion errors can be corrected in a relatively simple manner with a minimum of maneuvering. The proposed scheme takes advantage of the fact that in the rendezvous using an unmanned chase vehicle, the terminal phase must commence above the target vehicle. By portioning the time spent in a circular parking orbit below the target and time spent in the coelliptic orbit above the target at TPI altitude, the chase vehicle can be controlled to arrive on time at TPI despite large insertion dispersions.

K. E. Martersteck

K. E. Martersteck

1021-KEM-dcs

Attachments

References

1. Trip Report - Unmanned Rendezvous and Docking Meeting, MSC, January 29, 1968 - Case 610, by K. E. Martersteck, Memorandum for File, February 8, 1968.

2. W. M. Gillis, MSFC/R-AERO-DAP, Personal Communication

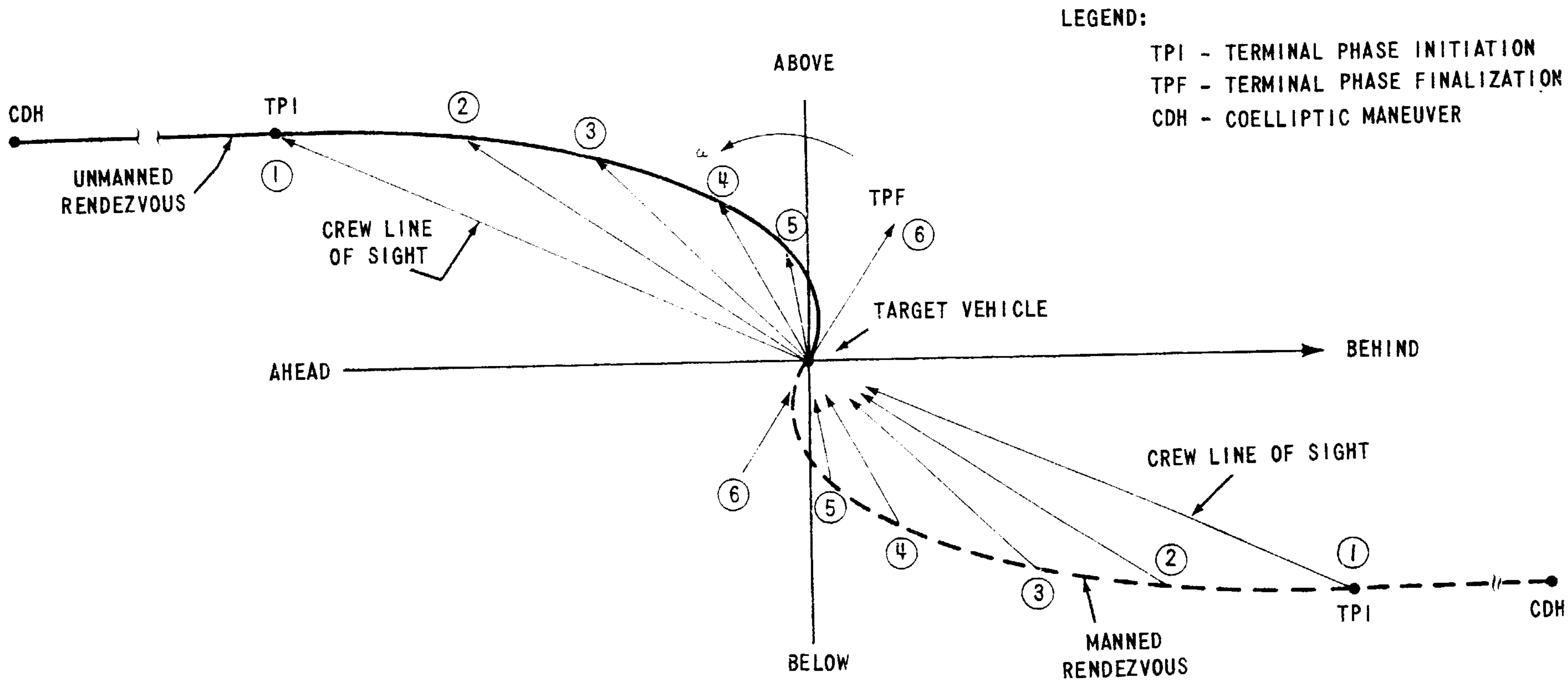

FIGURE 1 - RENDEZVOUS TERMINAL PHASE TRAJECTORIES

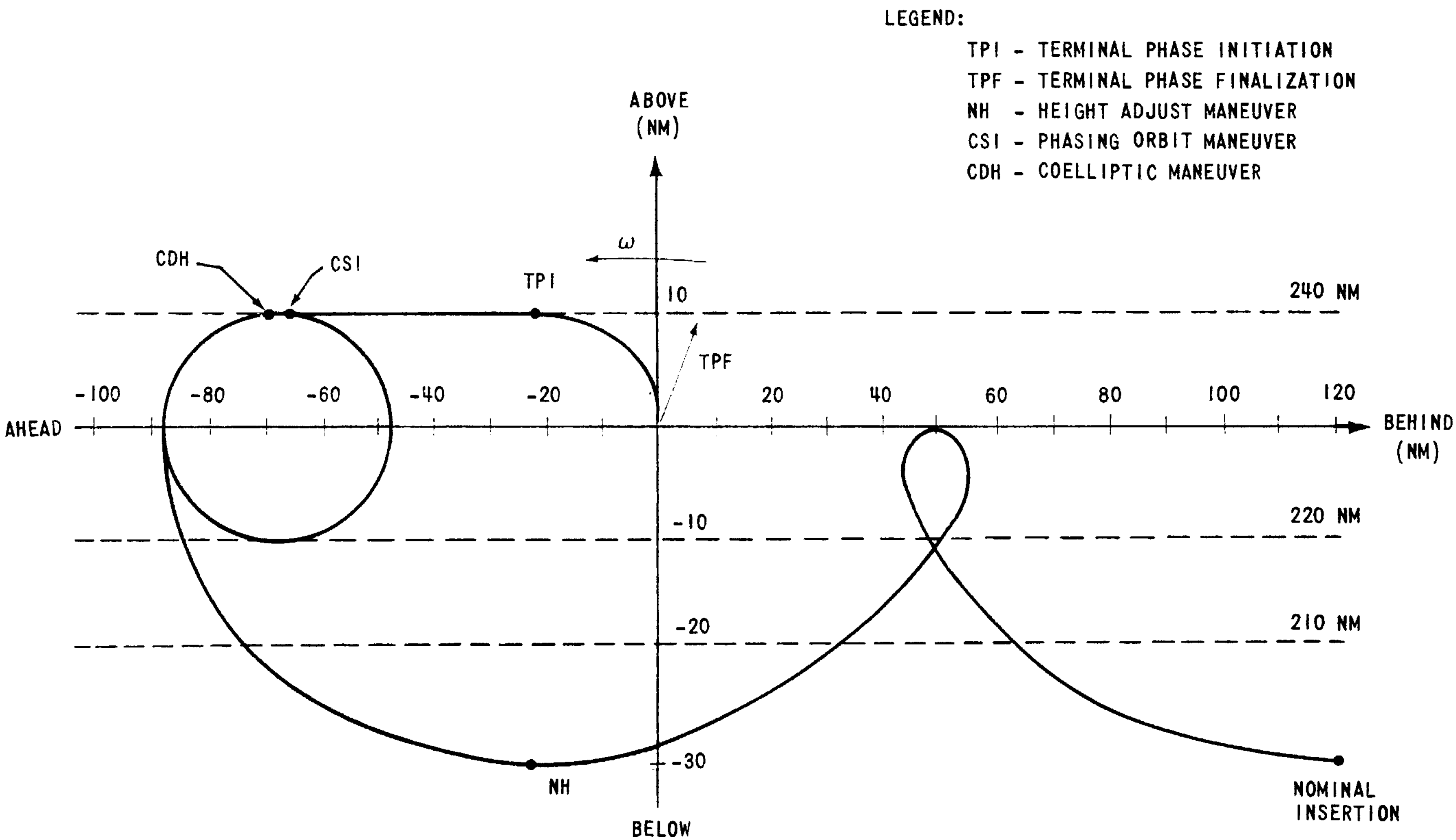

FIGURE 2 - TYPICAL RENDEZVOUS TRAJECTORY PROFILE

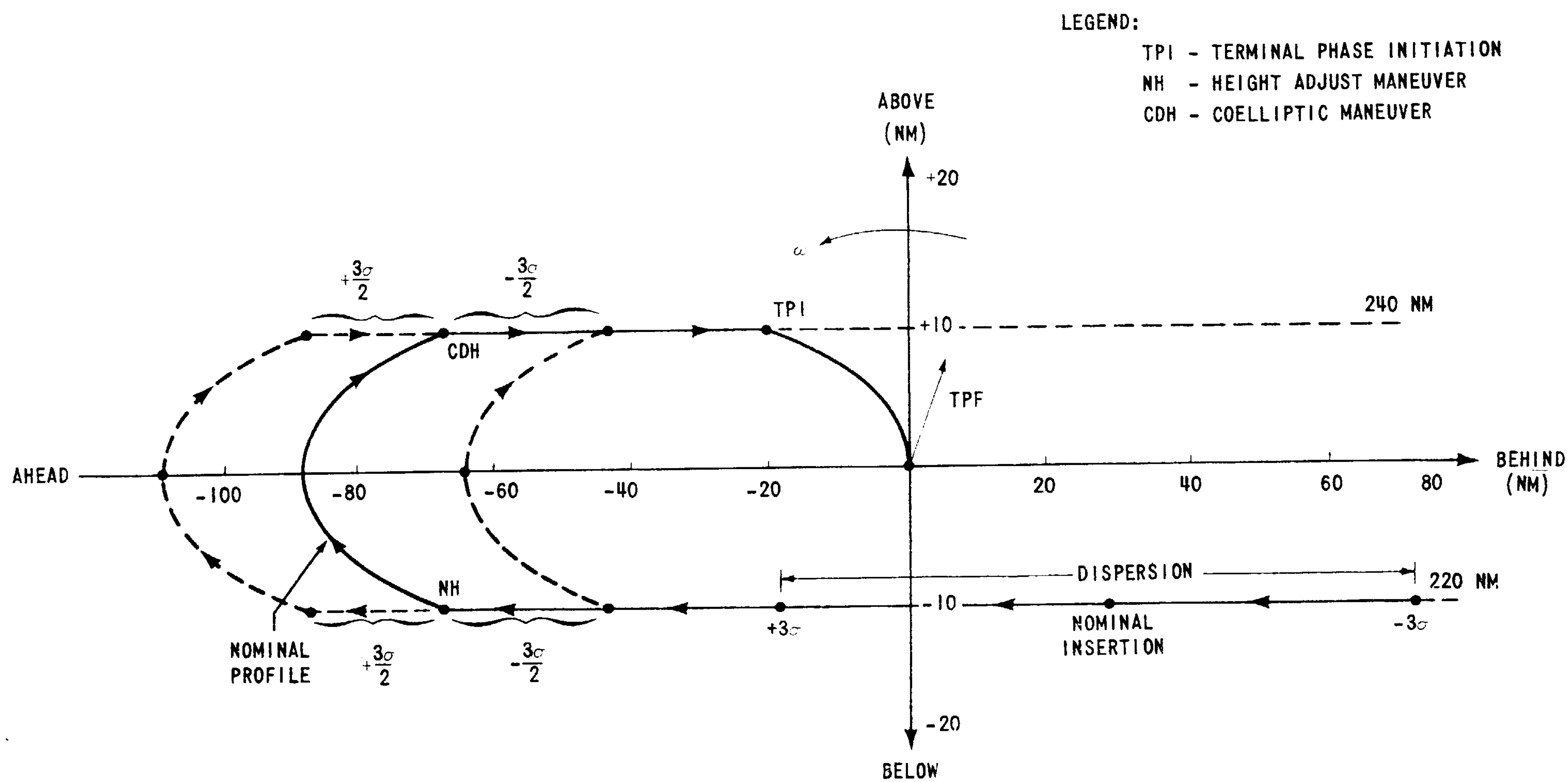

FIGURE 3 - UNMANNED RENDEZVOUS PHASING SCHEME